cisco or Fresno always add their portion to the white covering. The storms which extend out over Owens Valley, however, are few and far between, and when they do occur the yield rapidly decreases eastward from the mountains. At the Sierra crest the normal precipitation varies from about 40 inches at the head of Owens River to 25 inches back of Lone Pine. West of Independence it is about 32 inches at the crest, decreases to 15 inches at the upper edge of the outwash slopes (6,500-foot level), and is about 4 inches over most of the valley floor. Above the 6,500-foot level the precipitation is all in the form of snow, and at lower elevations occur as both rain and snow, but all values given represent the equivalent depth of water. Most of this precipitation occurs during the months of October to April. In the mountains there is little melting until summer, and the dry snow is soon blown off the exposed ridges into the canyons, where it accumulates in deep drifts. The only loss from it is by direct evaporation. On the alluvial slopes and the valley floor snow seldom remains unmelted more than 2 or 3 weeks.

The run-off conditions met with in the Owens Valley region are extreme. The mountain drainage basins yield all the precipitation upon them as surface flow, except *possibly 15 or 20 per cent which evaporates;* the alluvial slopes yield absolutely no surface run-off, for every drop of water which is not lost immediately by evaporation sinks into the ground; the valley floor sometimes yields flood run-off during a sudden thaw, but ordinarily absorbs all the precipitation falling upon it.

The streams which drain the mountain canyons increase in size from their source to the point where they emerge onto the alluvial slopes, and at this point their flow represents the difference between precipitation upon their catchment basins and evaporation. From here on, however, there are persistent losses by evaporation and by seepage into the porous formation of the valley fill. Careful measurements of 9 streams near Independence have shown that on the average *only 65 per cent of the water appearing at the mouth of canyons reaches a point one-half a mile west of the grass lands of the valley floor and that but 15 per cent reaches Owens River.* Between the first 2 points the evaporation loss is too small to consider, but in the valley floor where the water is used wastefully in irrigation it probably amounts to 30 or 35 per cent of the flow from the mountains. Therefore, in the region near Independence 50 per cent of the yield of these drainage areas is lost by seepage, about 35 per cent by immediate evaporation, and 15 per cent reaches Owens River.

The precipitation upon the alluvial slopes, although it does not appear on the surface, is not a loss, since probably 80 per cent of it sinks into the porous formation on which it falls, and together with the losses from stream channels percolates slowly eastward to join the great body of underground water beneath the valley floor.

The problem which then presented itself in the course of our study was: What becomes of the great volume of water which disappears into the valley fill? Luckily the valley is intersected at two places by rock ridges extending eastward from the base of the Sierra almost to the edge of the alluvial slopes fringing the Inyo Mountains. The cross-sectional area of the valley fill is greatly contracted at these points and much of the underflow southward is forced to the surface and appears in the channel of Owens River. It is thus possible to isolate sections of the valley and by careful measurement determine quantitatively the total volume of water entering the basin and a portion of the volume leaving it. Since the volume still unaccounted for could not accumulate indefinitely without appearing somewhere, there must be a definite outlet for it.

The significance of the meadow lands and the alkali in the valley floor then become apparent. *The water unaccounted for was passing into the atmosphere by evaporation and transpiration from the meadow land.* The fluctuation of the ground water surface represented the variation in the evaporation rate during the year, and the alkali deposit was left behind by the evaporated water. If spread over the 43 square miles of meadow lands in the basin in which Independence is located, the volume of water unaccounted for during one year would have a depth of 3.1 feet, or 56 per cent of the depth of evaporation from an exposed water surface in this region.

To test these conclusions a comprehensive series of tank experiments was planned for the purpose of measuring evaporation losses from soil and meadow grass. These experiments are still in progress, but they already show that, where the water-level is not more than 3 feet nor less than 1 foot below the surface, *that a depth of evaporation of about 80 per cent of that from an exposed water surface can be expected.* The experiments are to be carried on during the coming year for depths greater than 3 feet and under a variety of conditions, so that the results may be reliable as far as is possible under artificial conditions.

There is an interesting practical application of these ideas to the conservation of underground water supplies, which has been suggested by Mr. Mulholland. As noted above, *grasses do not grow, nor is there any alkali deposit where the depth to water exceeds 8 or 9 feet,* and also it has been found that ground-water fluctuations do not here obey the periodic law. It is therefore reasonable to conclude that no appreciable evaporation occurs from soil under such conditions. The lowering of the ground-water level under the meadow land by pumped or flowing wells in large numbers will eventually bring about a condition where evaporation losses will cease. The water that formerly was lost is then available for pumping, and further lowering of the water level will cease unless the pumpage exceeds the inflow into the underground reservoir. It has occurred to the writer that agricultural regions affected by rising ground water and alkali would do well to make a careful study of the local conditions, with these ideas in view.

THE OWENS VALLEY AND THE LOS ANGELES AQUEDUCT.

By A. B. WOLLABER, U. S. Weather Bureau, Los Angeles, Cal.

It is probable that no greater feat of engineering skill was ever attempted by a municipality than that now being carried on by the City of Los Angeles in bringing water from the Owens River, over rough mountains and a vast desert region, a distance of over 200 miles, to the storage reservoirs which will be located in the San Fernando Valley a few miles from the city.

The great Los Angeles Aqueduct is being pushed to completion at an astonishingly rapid rate and the dream of those intrepid engineers, who have every confidence in the practicability of this gigantic undertaking, is fast becoming a reality. The immensity of the project renders it of more than passing interest to the country as a whole, and it will no doubt prove of interest to the readers of the MONTHLY WEATHER REVIEW to know something of this important work, as well as to know something of the hydrological and climatological conditions covering the region whence this water supply is to be taken.

The rights and grants given to the Pueblo of Los Angeles by Spain as early as 1781 included a right to take and use all water of a stream that has since become known as the Los Angeles River, and which forms the outlet of a great subterranean reservoir known as the San Fernando Valley. These rights descended to the present city. It became apparent some years ago that the amount of water to be obtained through the medium of the Los Angeles River would soon be insufficient for the needs of the city, and a careful investigation was made of the possibilities for further water development in the neighborhood. These investigations disclosed the fact that it was practically useless to try to develop more water in this section, as the quantity obtainable would not meet the demands of future years, besides to draw further on the natural resources here would prove a serious menace to the future of the rich agricultural sections outside the city. It was finally determined that the only source offering water to meet the demands of this rapidly growing young city was that of the Owens River, a stream rising at an elevation of 12,000 feet among the high peaks of the Sierra, a little east of the main crest and about opposite the headwaters of the San Joaquin River.

As at present planned the water from the Owens River will be diverted from the main stream by an intake located at a point in the Owens Valley 2 miles south of Charleys Butte and about 12 miles north of Independence, Cal., at an elevation of 3,814 feet. Here the water will enter an unlined canal and be conveyed in this manner to the Alabama Hills below Lone Pine, Cal., thence through a system of conduits, tunnels, siphons, and flumes to the storage reservoirs in the San Fernando Valley near Los Angeles. Recent figures of the aqueduct engineers give the distances to be covered in this manner as follows:

	Miles.
Unlined canal	20.83
Covered conduit (lined)	100.35
Open conduit (not lined)	41.55
Tunnels	38.51
Siphons	13.08
Flumes	.25
Total	214.57

Several storage reservoirs are contemplated to regulate the flow of water, provide for dry years, breaks in the line, etc., one site having been located in Long Valley, on the Owens River above Round Valley, one at Haiwee on the line of the conduit 60 miles below the heading, and two at the end of the conduit at Fernando. The whole system when completed will provide for the delivery of the greatest possible amount of water from the Owens River and its tributaries at the end of the aqueduct line, thence to be distributed for the purposes intended.

The Owens River drainage basin lies wholly within the State of California, in Inyo and Mono counties, and is located east of the main crest of the Sierra. Its topography is varied. The Inyo and White mountains form its eastern watershed, while the Sierra Nevada Mountains bound it on the west. The basin is about 100 miles in length, has an approximate width of from 20 to 30 miles, and a total area of about 2,800 square miles, including Owens Lake. Its eastern slope is rough and rises to an elevation of some 6,000 feet above the floor of the valley. The western slope is precipitous, the mountains rising abruptly to an elevation of 12,000 feet above sea level, except that there is, in places, a sloping alluvial plain ranging anywhere from 1 to 5 miles in width. The range is dotted with peaks varying in elevation from 13,000 to over 14,500 feet, the highest of which is Mount Whitney.

The Owens Valley is comparatively level and the average elevation of the valley floor is about 3,900 feet. It has a gentle northward rise for a distance of 75 miles, where the grade becomes much steeper and quite rocky. There is a sparse timber growth and also several fertile valleys over the northern slope. While the floor of the valley is extensively cultivated, the slopes are almost devoid of vegetation, except a rank desert growth, and the only timber to be found is in the vicinity of the water courses and around the numerous small glacial lakes near the crest of the range where nearly all of the streams rise. These lakes serve in a way as natural reservoirs, regulating the flow of the streams during the run-off periods.

As previously stated the Owens River from which the City of Los Angeles will take its water supply rises in the high Sierra at an altitude of about 12,000 feet. It flows easterly into Long Valley, thence southward through a deep gorge known as Owens River Canyon, thence east and south through the valley, finally emptying into Owens Lake. The total length of the stream is about 100 miles. It receives no contributions from the valley itself and none from the eastern watershed, the streams that feed it coming wholly from the west. There are many of these creeks having their origin in the high Sierra; some comparatively small, others carrying a good flow of water, but all draining the east slope of the Sierra and deriving their supply from the melting snows. According to the engineers of the United

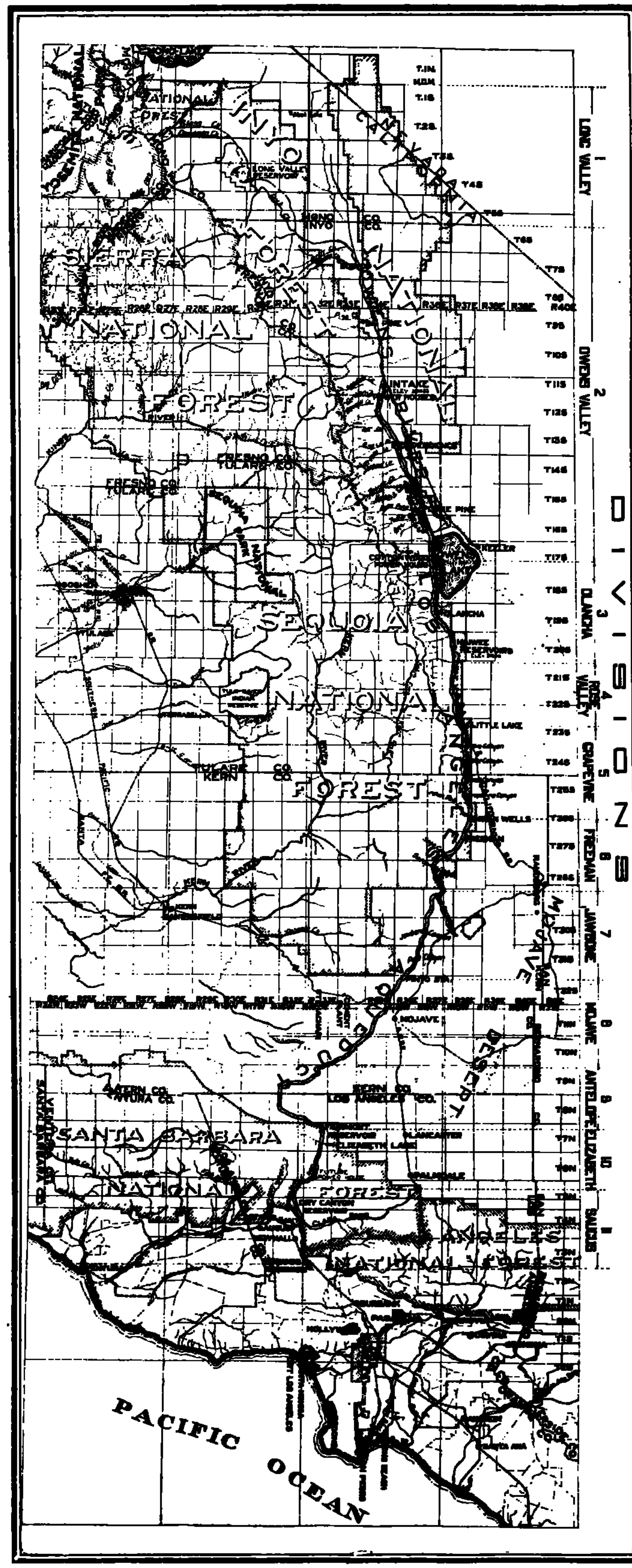

FIG. 1.—Showing line of the proposed Aqueduct from Owens Valley to Los Angeles, Cal.

States Geological Survey these streams have "a minimum flow in February and a maximum flow in June, their combined maximum being about 10 times their combined minimum". Of these tributaries the principal are Rocky, Pine, Horton, McGee, Birch, Bishop, Coyote, Baker, Big Pine, Tinemah, Taboose, Goodale, Division, Sawmill (Eight Mile), Thibaut, Oak, Shepard, Bairs (Moffit), Georges, Hogback, Lone Pine, Tuttle, Richter, Cottonwood, and Ash creeks. By courtesy of the engineers of the Los Angeles Aqueduct we are able to present a table showing the drainage areas of the principal streams emptying into the Owens River, from Taboosh to Ash Creeks. The data are compiled from the topographic maps of the United States Geological Survey:

Creek.	Total area.	Area above 8,000 feet.
	Sq. mi.	*Sq. mi.*
Taboose	7.1	6.1
Goodale	8.5	6.0
Division	7.0	4.4
Eight Mile	7.5	6.2
Oak	26.1	14.5
Independence	19.2	13.7
Shepard	12.5	11.6
Moffit	7.0	5.7
Georges	9.8	9.1
Lone Pine	14.0	12.6
Tuttle	8.5	7.3
Cottonwood	42.6	36.3
Ash	14.7	9.1

The creeks in this series having the most well-sustained flow in low-water period are Taboose, Division, Eight-mile, and Cottonwood. Those having the largest total yearly discharges are Taboose, Oak, Independence, Lone Pine, and Cottonwood.—*First Annual Report Los Angeles Aqueduct, 1907.*

The climatic features of the Owens Valley are pretty well known through the medium of the regular Weather Bureau office maintained at Independence since 1898. The conditions at that point are fairly typical of the valley proper, except that in all probability there is an increase in precipitation over the western and northern slopes, due to overreaching storms at the summit of the range. The accompanying table gives the precipitation at Independence and shows an average of 4.22 inches annually.

Careful estimates place the average annual precipitation for the whole valley in the neighborhood of 6 inches. Little is known except in a very general way of the distribution of rainfall over the higher levels, and the only way whereby any idea can be formed of this amount is by comparison with that on the westward side of the range where records have been kept for a number of years. The moisture-bearing winds of the Pacific deposit great quantities of precipitation on the westward side of the Sierra, the increase being rapid from the valley floor up to between the 3,500 and 5,000 foot levels, after which there is a decrease to the summit. The increase with elevation amounts to from 40 to 80 inches annually, and it is quite probable that the average fall at and just east of the summit is in the neighborhood of 50 inches. It is from this source of supply that all of the tributaries of the Owens River derive their run-off. About a year ago the aqueduct engineers placed a series of rain gages at different elevations on Taboose, Oak, and Bairs creeks in order to obtain a record of the precipitation over a part of the drainage basins of these streams. These are 3 groups consisting of 5 gages each, located as nearly as practicable at each 500-foot level, beginning at an elevation of approximately 4,000 feet. The accompanying tables, furnished by Mr. Chas. H. Lee, Assistant Engineer of the Los Angeles Aqueduct, give the locations of the gages and the record obtained during the season of 1908–1909. (See map on page 128.)

Number of gage.	Group.	Elevation of gage.	Distance from crest of Sierra.	Remarks.
		Feet.	*Miles.*	
1		3,820	8.0	In valley floor.
2	Taboose	4,070	8.0	At edge of valley floor.
3	do	4,460	6.85	On outwash slope.
4	do	5,040	5.5	Do.
5	do	5,550	4.7	At base of mountain.
6	do	6,190	4.2	On slope of mountain.
7	Oak	3,940	9.6	At edge of valley floor.
8	do	4,300	8.35	On outwash slope.
9	do	5,030	6.55	Do.
10	do	5,590	5.65	Do.
11	do	6,120	4.75	At base of mountain.
12	Bairs	4,100	10.2	At edge of valley floor.
13	do	4,500	8.95	On outwash slope.
14	do	5,000	7.7	Do.
15	do	5,500	6.6	Do.
16	do	6,100	5.6	At base of mountain.
U. S. W. B. at Independence		3,925	9.6	At edge of valley floor.

This record shows quite a uniformity in the amounts collected on Taboose and Oak creeks during the first year, but considerably less amounts on Bairs Creek. This decrease is probably due to the general decrease of the precipitation toward the south and to the presence of Mount Whitney, near whose base this stream flows. A study of the records obtained from these gages for a number of years will prove extremely interesting, as in this manner some idea can be obtained of the distribution of precipitation over the eastern slope of the range. During the summer of 1909 the Weather Bureau established mountain snowfall stations at the Bishop Creek Gold Company's camp on Bishop Creek and at the Wells Meadow Ranger Station in Round Valley, but no records have as yet been obtained from either station. The abundant discharges of the several creeks flowing from the snow fields near the summit of the Sierra give the best evidence of the generous precipitation near their headwaters. Through the courtesy of the engineer in charge of the hydrological work of the United States Geological Survey in this State we are enabled to give a table showing the run-off of the Owens River and its tributaries for the last several years. The longest run-off record in the Owens River Basin extends back to 1903, when gaging stations were established on the main stream and on Rock and Pine creeks near Round Valley and on Bishop Creek near Bishop. Since that time stations have been put in on all of the principal tributaries. Records are now being kept at the following points throughout the drainage basin:

Owens River near Round Valley.
Owens River near Los Angeles Aqueduct intake.
Rock Creek near Round Valley.
Pine Creek near Round Valley.
Bishop Creek near Bishop.

Monthly, seasonal, and annual precipitation, 1898–1909, at Independence, Cal.

Season.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March.	April.	May.	June.	Seasonal.	Year.	Annual.
1898—99	T.	0.11	0.20	0.00	0.10	0.20	0.54	T.	0.01	0.02	0.03	0.37	1.58	1899	2.75
1899—1900	0.01	0.06	T.	0.30	0.85	0.56	0.31	0.05	0.67	0.62	0.22	0.04	3.69	1900	4.22
1900—01	0.08	T.	0.75	0.01	1.34	0.13	2.81	0.64	0.05	T.	0.36	0.00	6.17	1901	5.21
1901—02	0.10	0.32	0.00	0.65	0.22	0.06	0.04	1.69	1.05	0.17	0.04	0.01	4.35	1902	3.83
1902—03	0.17	0.13	T.	0.08	0.41	0.04	0.71	0.27	0.34	0.19	T.	0.02	2.36	1903	1.95
1903—04	0.00	0.00	T.	0.42	T.	0.00	T.	1.20	0.95	T.	0.02	0.00	2.59	1904	2.62
1904—05	T.	0.07	0.32	0.06	0.00	T.	0.54	0.73	2.08	T.	0.25	0.00	4.05	1905	4.28
1905—06	0.00	T.	0.25	0.00	0.43	T.	2.89	0.13	1.86	0.36	0.42	0.10	6.44	1906	6.97
1906—07	0.31	0.04	0.00	T.	0.02	0.84	0.95	0.56	1.10	0.14	0.01	0.55	4.52	1907	5.85
1907—08	T.	0.00	0.00	2.12	T.	0.42	1.63	0.98	0.14	T.	T.	T.	5.29	1908	4.55
1908—09	0.26	0.46	0.84	0.03	0.01	0.20	3.27	2.73	0.16	0.12	T.	T.	8.08	1909	....
Averages (11 years)	0.08	0.12	0.21	0.33	0.31	0.22	1.24	0.82	0.76	0.15	0.12	0.10	4.47	....	4.22

Precipitation records near Independence, Cal., 1908–09.

Number of gage.	Station.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Total.
		Ins.	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*
1	Taboose	(0.84)	0.14	T.	0.16	3.51	3.00	0.23	0.22	0.00	0.00	0.00	(0.20)	8.30
2	...do...	(0.85)	0.06	(T.)	0.15	4.52	3.22	0.24	T.	0.00	0.00	0.00	(0.05)	9.09
3	...do...	(0.85)	0.04	(T.)	0.27	4.85	4.02	0.28	0.04	0.00	0.00	0.00	(0.05)	10.40
4	...do...	(5.90)	0.05	(T.)	0.26	6.32	3.77	0.37	0.02	0.00	0.00	0.00	(0.05)	11.74
5	...do...	(0.95)	0.12	(0.10)	0.28	8.93	5.23	0.80	0.02	0.00	0.00	0.00	(0.10)	16.53
6	...do...	(1.00)	(0.17)	(0.15)	(0.12)	(12.69)	7.49	1.42	0.05	0.00	0.00	0.00	(0.15)	23.24
7	Oak.....	(0.85)	(0.04)	T.	0.19	3.44	2.52	0.12	0.02	0.00	0.00	0.00	0.04	7.22
8	...do...	(0.85)	(0.05)	T.	0.21	4.65	3.06	0.36	0.00	0.00	0.00	0.00	0.06	9.24
9	...do...	(0.90)	(0.06)	T.	0.25	5.89	3.49	0.71	0.00	0.00	0.00	0.00	0.05	11.35
10	...do...	(0.95)	(0.10)	0.08	0.25	7.69	4.62	0.71	0.00	0.00	0.00	0.00	0.07	14.47
11	...do...	(1.00)	(0.15)	0.23	0.31	11.49	6.61	1.68	0.02	0.00	0.00	0.00	0.15	21.04
12	Bairs...	(0.85)	T.	(T.)	0.22	1.53	1.53	0.15	T.	0.00	0.00	0.00	T.	4.28
13	...do...	(0.85)	T.	(T.)	0.26	2.67	2.06	0.15	0.00	0.00	0.00	0.00	0.10	6.09
14	...do...	(0.90)	T.	(T.)	0.27	3.48	2.56	0.29	0.00	0.00	0.00	0.00	0.13	7.63
15	...do...	(0.95)	0.14	(0.10)	0.29	5.05	4.36	0.63	T.	0.00	0.00	0.00	0.15	11.67
16	...do...	(1.00)	0.28	(0.15)	0.29	6.43	4.98	1.06	0.07	0.00	0.00	0.00	0.14	14.34
U. S. Weather Bureau, at Independence	....	0.84	0.03	0.01	0.20	3.27	2.73	0.16	0.12	T.	T.	0.00	0.25	7.61

Values in parentheses are estimated by C. H. Lee.

Baker Creek near Big Pine.
Big Pine Creek near Big Pine.
Birch Creek near Tinemaha.
Tinemaha Creek near Tinemaha.
Taboose Creek near Tibbetts.
Goodale Creek near Tibbetts.
Division Creek near Tibbetts.
Sawmill (Eight Mile) Creek near Independence.
Thibaut Creek near Independence.
Oak Creek near Independence.
Independence Creek near Independence.
Shepards Creek near Thebe.
Bairs (Moffit) Creek near Independence.
Georges Creek near Thebe.
Lone Pine Creek near Lone Pine.
Tuttle Creek near Lone Pine.
Cottonwood Creek near Olancha.
Ash Creek near Olancha.

The following table shows the mean yearly discharge of the Owens River and its principal tributaries:

Gaging stations.	1904	1905	1906	1907	1908
	Sec.-ft	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
Owens River near Round Valley	287.0	216.0	358.0	381.0	241.0
Rock Creek near Round Valley	40.3	26.2	63.7	60.0	31.0
Pine Creek near Round Valley	34.0	16.6	44.4	46.7	14.7
Bishop Creek near Bishop	111.0	83.5	166.0	12.6	78.7
Big Pine Creek near Big Pine	49.1	53.5	....	58.0	40.0
Taboose Creek near Tibbetts	....	....	12.1	9.5	5.1
Goodale Creek near Tibbetts	....	....	6.0	5.9	3.9
Division Creek near Independence	....	....	9.7	10.2	7.1
Oak Creek near Independence	....	....	35.0	22.7	15.0
Independence Creek near Independence	....	15.1*	31.1	21.8	11.2
Shepards Creek near Thebe	....	....	....	11.0	7.4
Bairs Creek near Independence	....	....	....	4.7	1.9
Georges Creek near Thebe	....	....	....	9.4	7.0
Lone Pine Creek near Lone Pine	....	....	31.1	23.0	19.6
Tuttle Creek near Lone Pine	....	....	15.4	9.9	8.2
Cottonwood Creek near Olancha	....	....	75.8	40.4	27.8
Ash Creek near Olancha	....	....	8.8	10.0	5.1

* For June to December.

FLOODS IN SOUTHERN CALIFORNIA.

By A. B. WOLLABER, Local Forecaster, Los Angeles, Cal.

From December 30, 1909, to January 2, 1910, heavy rains fell in southern California. In the valleys the amounts ranged between 3 and 4 inches, while in the foothills and mountains, to the north and east, from 10 to 16 inches fell during the storm. The rain was accompanied by warmer weather than usual and the snow on the higher levels melted rapidly, causing a rapid rise in all mountain streams, which soon became raging torrents carrying a heavy flow to the valleys below. Even the small washes that have been dry for years were running bank full and while nearly all streams overflowed their banks in places the greatest damage was done by the San Gabriel River, which left the new bed formed by this stream during the flood of 1874 and returned to the old channel, inundating many acres of rich farming land and orchards and carrying out bridges in many places. The area flooded by this stream in the vicinity of Los Angeles was about 5 miles long and from ½ to ¾ of a mile in width. Near Santa Ana several hundred acres of rich celery land were also covered and that portion of the crop not already marketed was practically ruined.

Railroads, both steam and electric, suffered the most damage, all transcontinental trains being badly delayed by washouts, while the suburban service to the flooded districts had to be abandoned. It is difficult to estimate the loss occasioned by the flood, but conservative estimates place the total in this section between $200,000 and $250,000.

No river and flood service is maintained by the Bureau in this section and no warnings were issued, except the usual rain warnings sent out before each big storm.

FIG. 2.—Snow fields near the top of the Kearsage Trail, Sierra Nevada Mountains, to the West of Independence, Owens Valley, Cal., July 10, 1909, at an elevation of 10,000 feet.

FIG. 3.—Snow field and open water in lake on the Kearsage Trail, July 10, 1909.

FIG. 4.—Snow in the forest near lake on the Kearsage Trail, July 10, 1909.